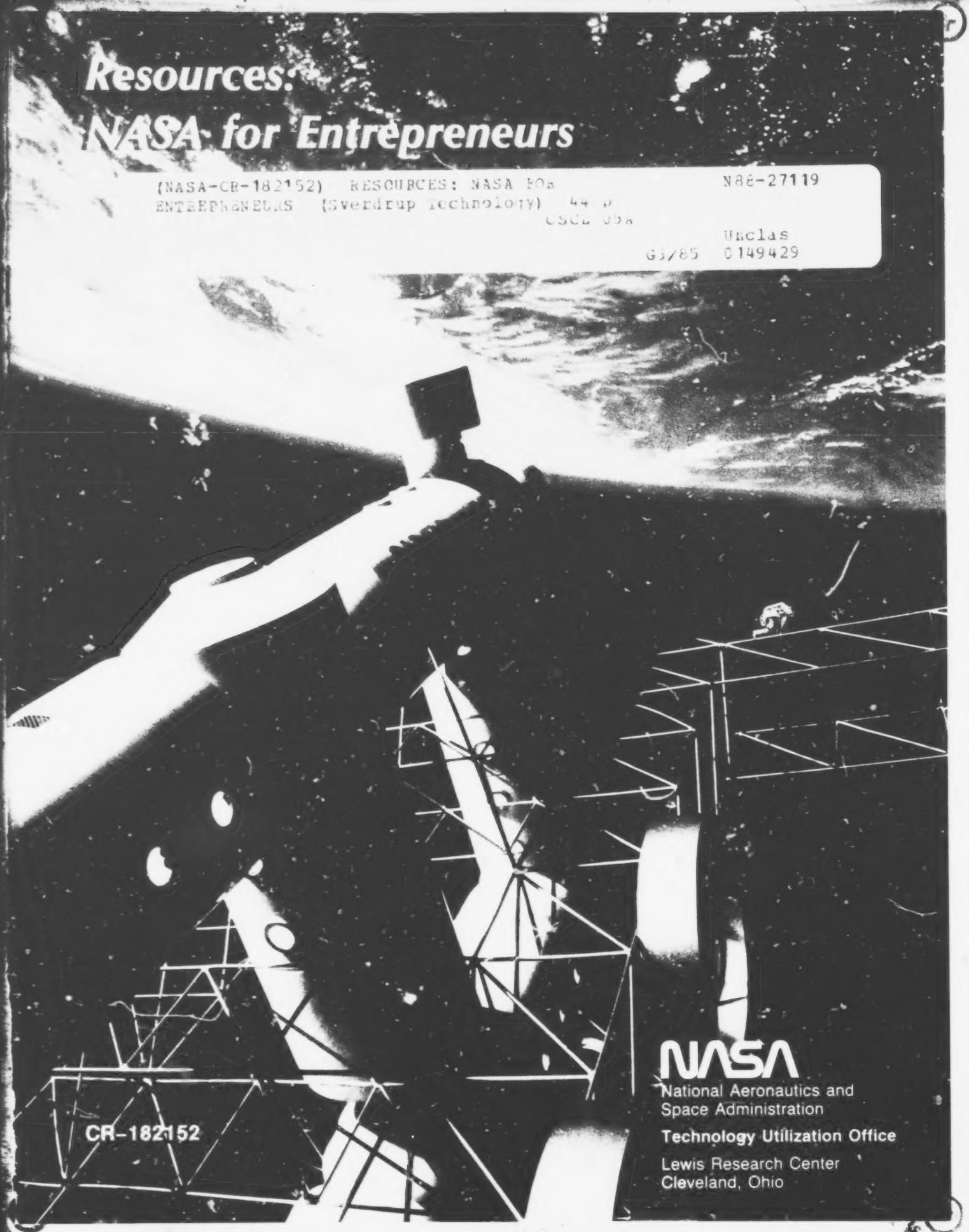
Resources: NASA for Entrepreneurs

(NASA-CR-182152) RESOURCES: NASA FOR ENTREPRENEURS (Sverdrup Technology) 44 p CSCL 05A

N88-27119

Unclas

G3/85 0149429



NASA

National Aeronautics and Space Administration

Technology Utilization Office

Lewis Research Center
Cleveland, Ohio

CR-182152

NASA Contractor Report 182152

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

Resources:
NASA for Entrepreneurs

NASA
National Aeronautics and
Space Administration

Technology Utilization Office

Lewis Research Center
Cleveland, Ohio
1988

communications satellite

ORIGINAL PAGE
COLOR PHOTOGRAPH

Foreword

From Satellite Balloons to Greeting Card Balloons
Technology Utilization Comes Full Circle

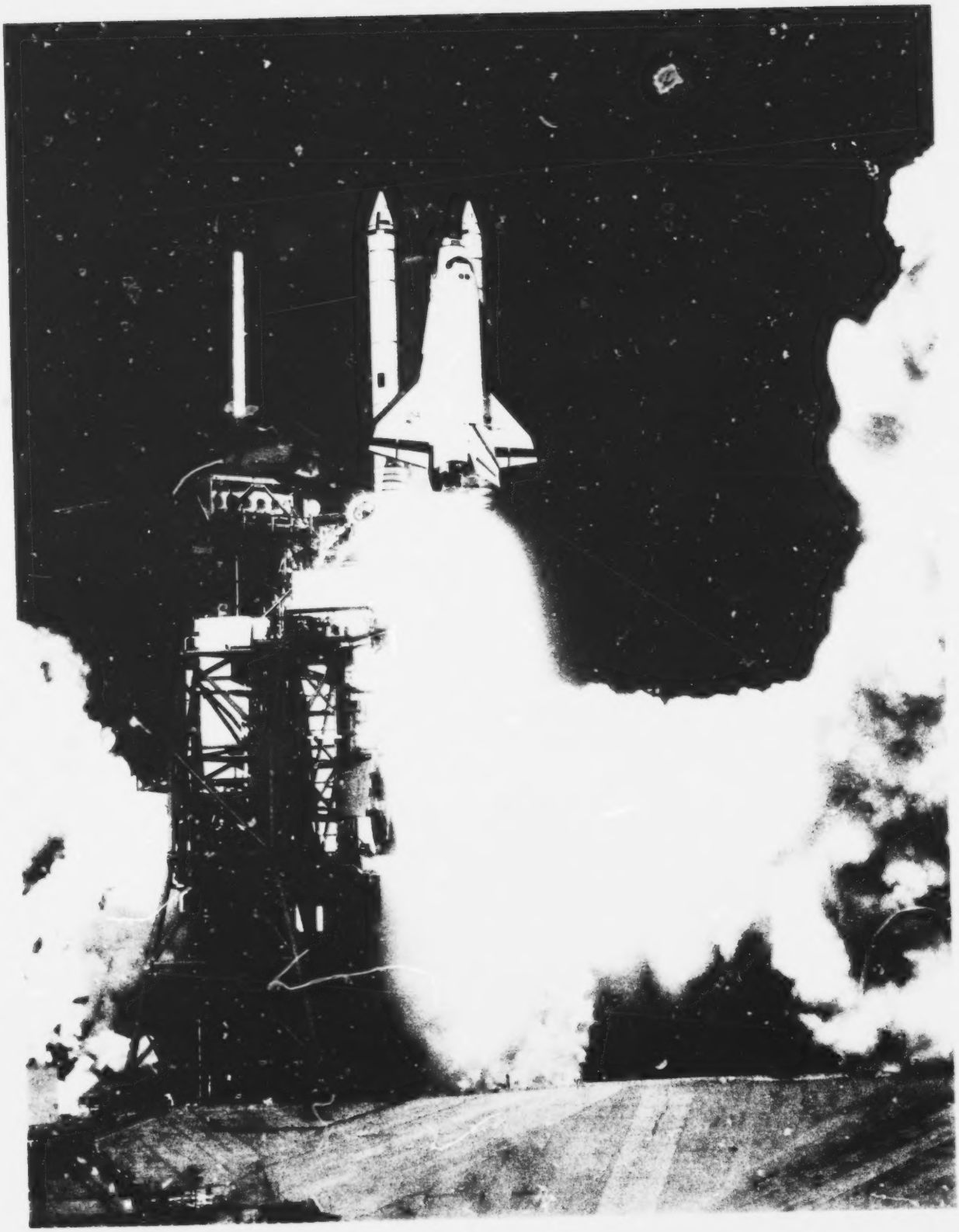
Echo's Legacy

Twenty years ago, if you lay back on your newly mowed lawn to admire the night sky, you might have seen a glistening dot drifting along at a steady pace. After a few moments, you realized the dot was Echo I, NASA's first communications satellite. A large, shiny balloon, Echo I relayed communication signals between points on Earth. Today the same shiny material sends greeting card messages on bouquets of colorful helium balloons.

The Echo story illustrates the full circle of the technology utilization process. In the early days of spaceflight, clothing fashioned from Echo's Mylar fabric made long-distance voyagers more comfortable. Through the efforts of the Technology Utilization Program, Echo's legacy now embraces a wide range of products including bulk-free outdoor clothing for Earth-bound travelers.

For two decades NASA has promoted thousands of spinoff innovations that contribute to the quality of American life and bolster the economy. After reading this brochure, you may agree that spinoffs, indeed, represent a substantial return on your aerospace investment.

ORIGINAL PAGE
COLOR PHOTOGRAPH



Space shuttle launch

ORIGINAL PAGE
COLOR PHOTOGRAPH

Introduction

for the benefit of all mankind —*Space Act 1958*

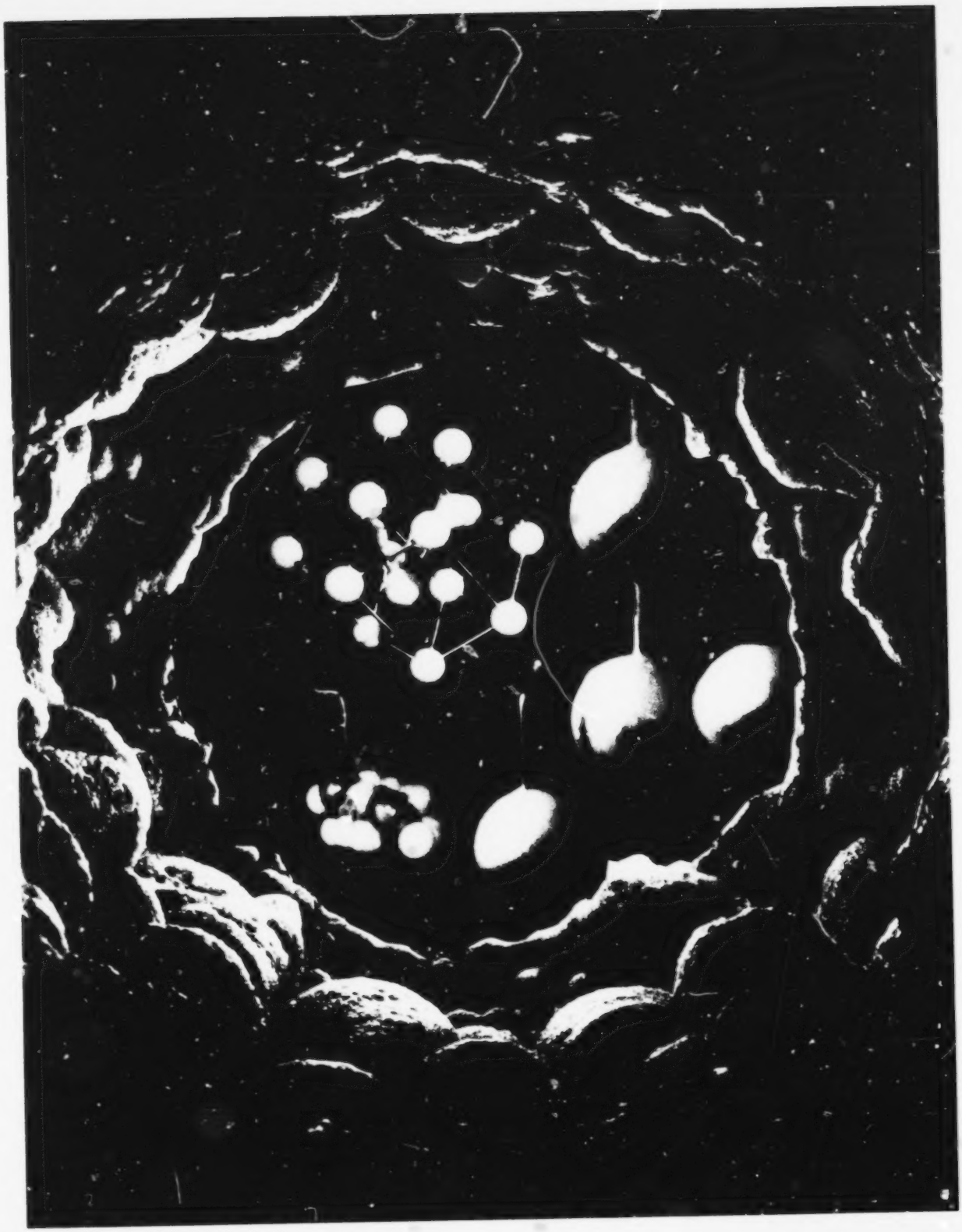
When the Space Act of 1958 established the National Aeronautics and Space Administration, NASA initiated a system for transferring its aerospace research to the aerospace industry. This affiliation encouraged state of the art innovations in the field. A few years later, NASA recognized the terrestrial potential of aerospace technology and established the Technology Utilization Program.

Since its inception, the Technology Utilization Program has spawned thousands of spinoff products ranging from automotive engines to frozen food wrappers. This spinoff success inspired the 1980 Stevenson Wydler Act, which formalized the Government's affiliation with American business by requiring all Federal research laboratories to actively transfer new technology to the private sector. As a result of NASA's achievements, other Federal laboratories modeled the Technology Utilization Program. The 1986 amendment to the Stevenson-Wydler Act expanded the Technology Utilization Program by setting aside Government funds for service to the private sector.

The Technology Utilization Program routinely offers NASA's research to any United States company that seeks NASA's know how. However, few citizens are aware that NASA offers its expertise to American entrepreneurs who run part time businesses from a garage as frequently as it advises large computer manufacturers. Most requests, in fact, involve ordinary technical problems.

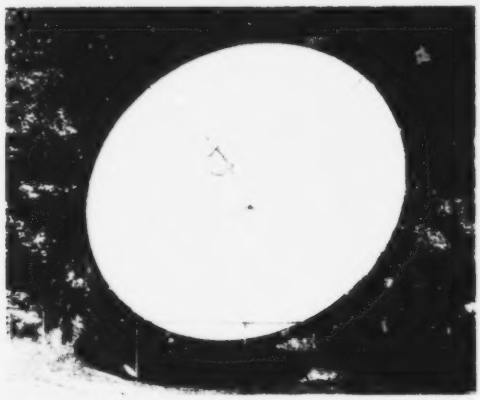
For example, a pottery firm may seek an insulating material for maintaining uniform temperatures in their kilns. Perhaps they are testing a new ceramic and need research information. A technology utilization officer may solve the problem in a series of telephone conversations or by referring the requestor to a knowledgeable scientist. The Technology Utilization officer can also recommend other NASA field centers and over 300 federal research laboratories.

This brochure details the services of the Technology Utilization Program and highlights spinoff products in various stages of completion. With a little ingenuity, the next successful NASA spinoff can be yours.



Volcano rocket chamber

ORIGINAL PAGE
COLOR PHOTOGRAPH



Contents

9 The Lewis Research Center

12 NASA's Technology Utilization Program

15 Technology Utilization Services

19 From the Research Laboratory to the Marketplace

22 A New Engine for the Automotive Industry

25 Cutting Power Costs for UHF-TV Stations

26 Jet Fuel Conservation Serves the World of Sports

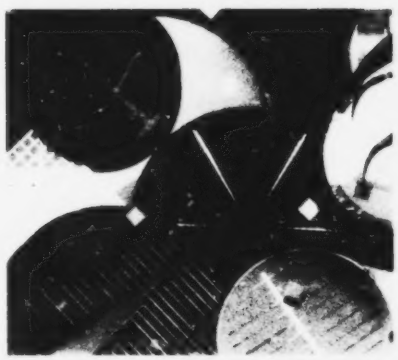
29 Reinforced Plastic for High Temperature Applications

30 Giving New Life to Lady Liberty

32 From Fuel Pumps to Heart Pumps

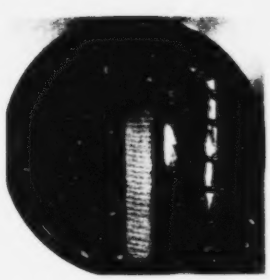
35 Resources

40 Acknowledgments



ORIGINAL PAGE
COLOR PHOTOGRAPH

ORIGINAL PAGE
COLOR PHOTOGRAPH



Aerial view of NASA's Lewis Research Center

ORIGINAL PAGE
COLOR PHOTOGRAPH

The Lewis Research Center

Reaching for the Stars

During the past 46 years, thousands of Lewis Research Center employees have worked on projects for America's aerospace program. While some of their innovations head toward the stars, many of their products have been recognized by the research community here on Earth.

For example, each year *Research & Development* magazine recognizes 100 of the most significant new technical products. Since 1966, 53 products from Lewis have received the distinguished "IR-100" Award. On the all-time winner's list, Lewis ranks fifth, and NASA as a whole ranks second with 73 awards. Considering that the other members of the top five are Fortune 500 companies (General Electric, Varian Associates, and Westinghouse), this is a notable achievement.

While NASA's mission is to develop technology "for the benefit of all mankind," the Lewis Research Center is NASA's primary field center for aircraft, rocket, and automotive propulsion. In recent years Lewis has taken the lead in power generation and space communications programs. These areas provide Lewis' scientists and engineers with the opportunity for sharing their new technology with their countrymen. The following overview of the research directorates describes the broad range of programs being conducted at Lewis.

The Aeronautics Directorate

Since 1941 the Aeronautics Directorate has been a pioneer in developing advanced aircraft propulsion systems. Its research is divided into a theory group and an applications group. The Internal Fluid Mechanics Division focuses on computational methods and computer modeling. The Propulsion Systems Division emphasizes research and development in applications such as gas-turbine engines, rotary engines, advanced high-speed turboprops, rotorcraft, propeller technology, and aircraft icing. The heart of aerospace research includes high-temperature, high-strength materials, fluid dynamics, reaction kinetics, heat transfer, acoustics, combustion, and aerodynamics.

The Aerospace Technology Directorate

The Materials Division develops advanced materials to support Lewis' aerospace mission. High-temperature metal alloys, metal composites, ceramics, and high-temperature polymers are tested for aircraft engines, and lightweight composites are tested for aerospace structures. Bearings and lubrication materials are also studied. The Microgravity Materials Science Laboratory supports NASA's planning for low-gravity research projects for the space station.

As a companion to the Materials Division, the Structures Division specializes in structural mechanics, fatigue, fracture mechanics, structural dynamics, structural integrity, and advanced concepts.

The Power Technology Division develops power generation systems. Its research programs encompass photovoltaics, energy storage, space systems, nuclear systems, fuel cells, and the Stirling cycle engine. The division is also working on improving the electrical properties of advanced materials.

The Space Electronics Division does research in all areas of space electronics and communications, including antenna systems, electron-beam technology, superconductivity, and solid-state and digital-systems technology.

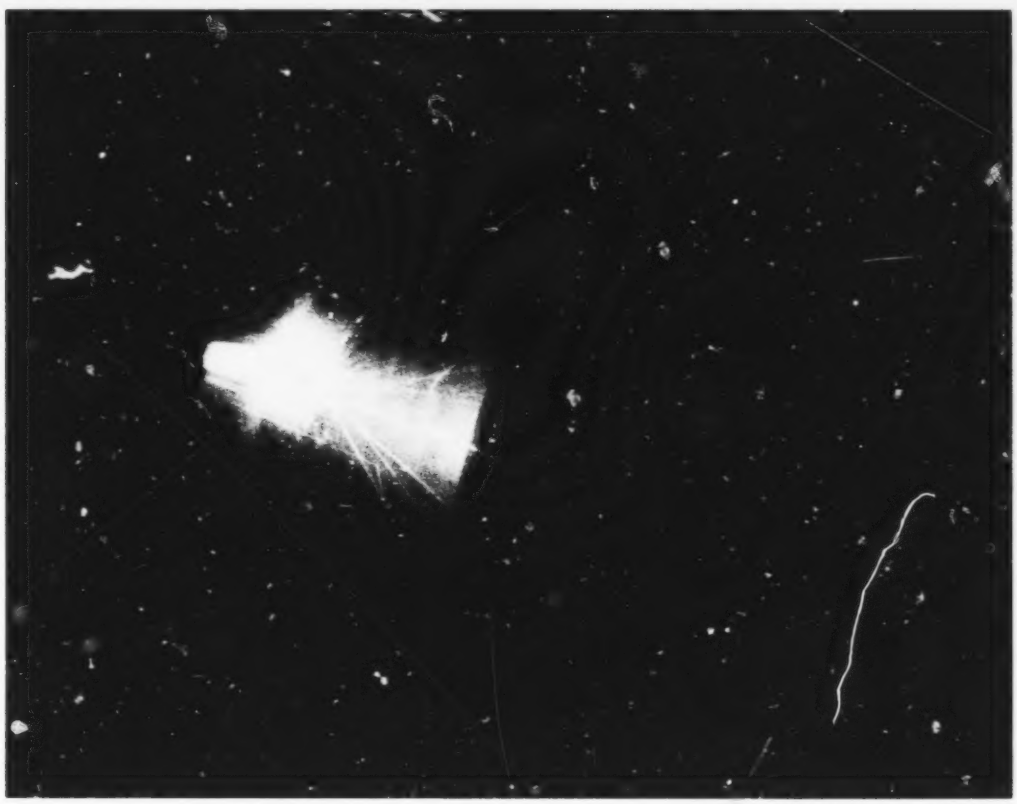
The Space Propulsion Technology Division develops electric propulsion systems for deep-space vehicles and for the space station. This division is also concerned with tracking satellites.

The Space Flight Systems Directorate

This directorate focuses on specific spaceflight projects rather than general research. For example, NASA's workhorse, the Atlas Centaur is one of the country's most successful launch vehicles. The Advanced Communications Technology Satellite Project Office has the mission of developing higher capacity communications satellites. Technical areas include high-frequency electronics and solid-state technology with emphasis on high-speed switching circuits.

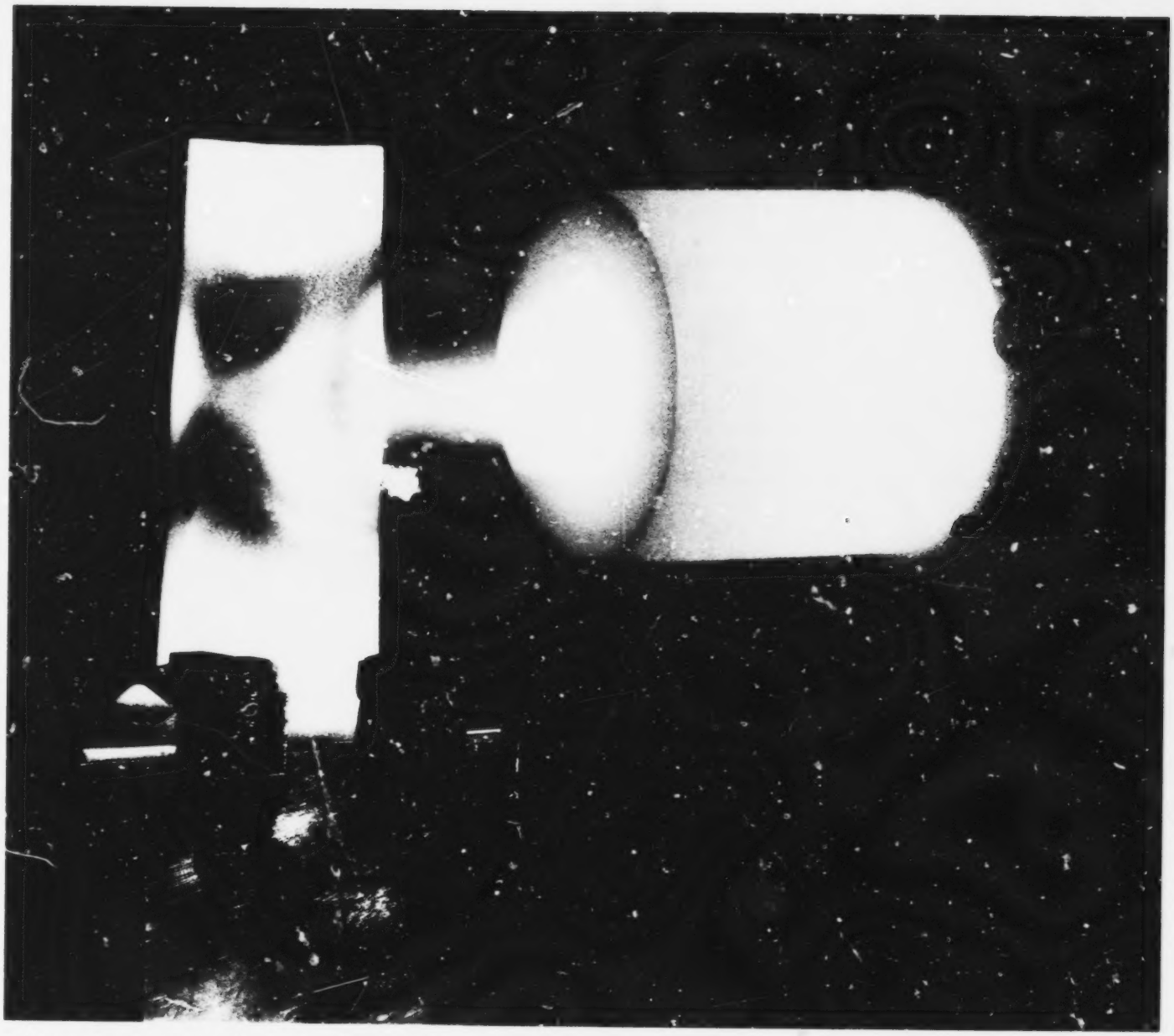
The Space Station Systems Directorate

The design and construction of the electrical system for the space station is the primary mission for this directorate. The electrical system will include batteries, photovoltaics, and solar dynamics. If the space station houses an international crew, the system will need to accommodate a wide variety of voltages and frequencies.



The arc spray technique, an IR-100 Award winner.

ORIGINAL PAGE
COLOR PHOTOGRAPH



Testing ceramic coatings in Mach-6 combustion rig

BLANK PAGE
POOR QUALITY REPRODUCTION

NASA's Technology Utilization Program

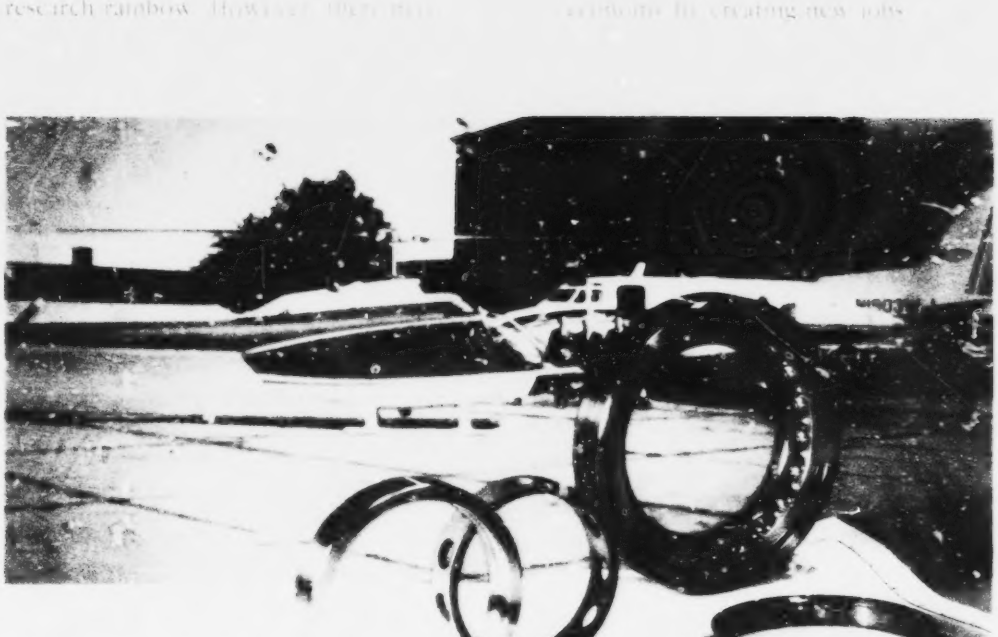
A Pot of Gold for American Industry

Whether you're tackling a small project or a major venture, the Technology Utilization Program is eager to share NASA's products and procedures with you. While TU officers do not act as general consultants, they do serve two major audiences: entrepreneurs and industry. First, the officers seek American entrepreneurs with ideas for innovative products or markets. Second, they provide technical solutions for industries with existing products or manufacturing processes.

While you've heard the saying "There's no free lunch," the Technology Utilization Program is an exception to that rule. You will be pleased to learn that, in general, NASA does not charge for this pot of gold at the end of the research rainbow. However, there may be a nominal licensing fee for the use of patented inventions.

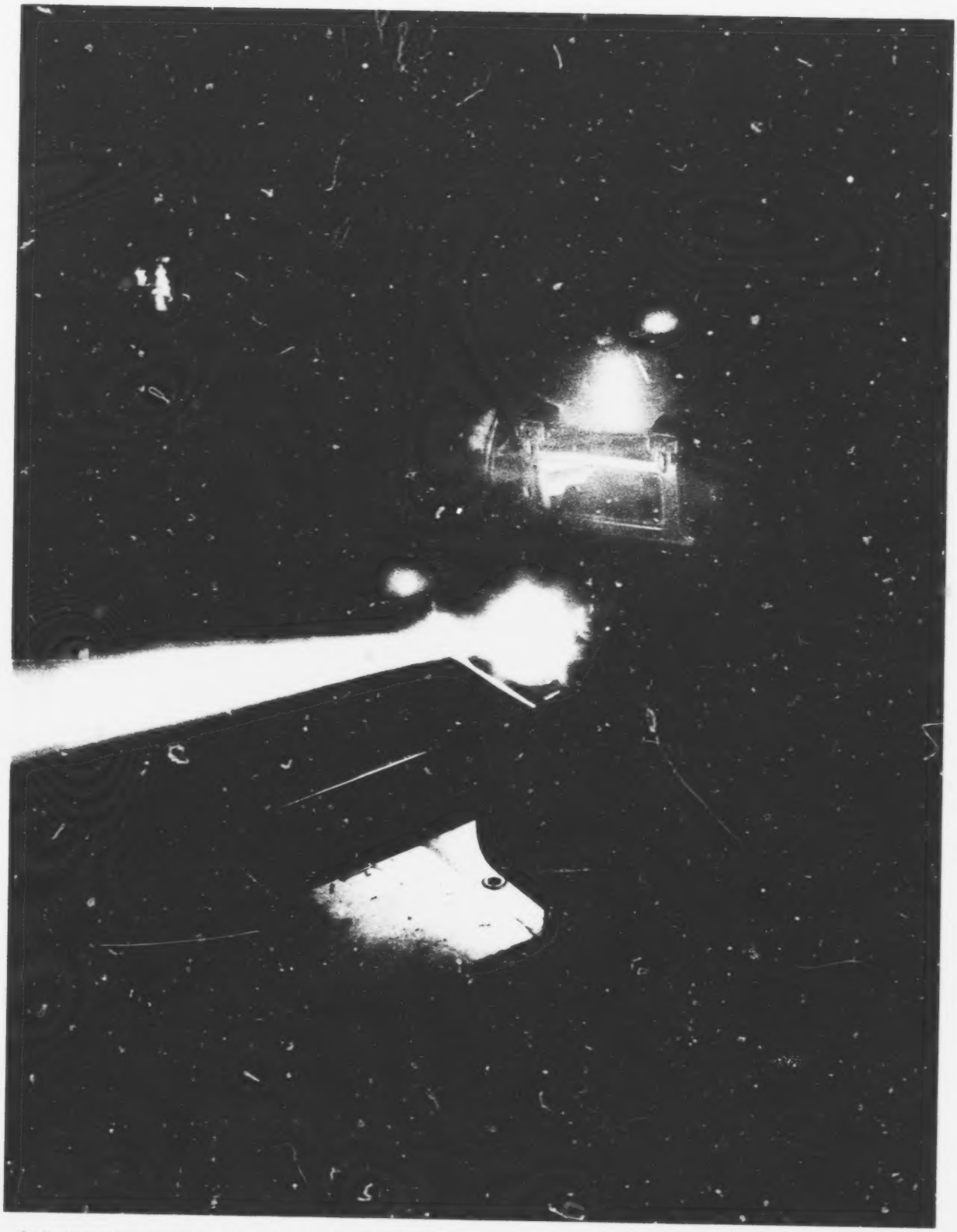
Just as a business associate may refer you to a resource, the Technology Utilization Program acts as a resource for NASA technology. The TU Program goes one step further, however, to develop a client relationship. If two companies have a mutual interest in a product, NASA may bring these companies together. Otherwise, all requests are confidential. Usually, paperwork is required only when patents or licenses are involved.

Since American tax dollars support NASA's research, TU officers are enthusiastic in assisting the private sector. Successful NASA spinoffs promote competition and boost the economy by creating new jobs.



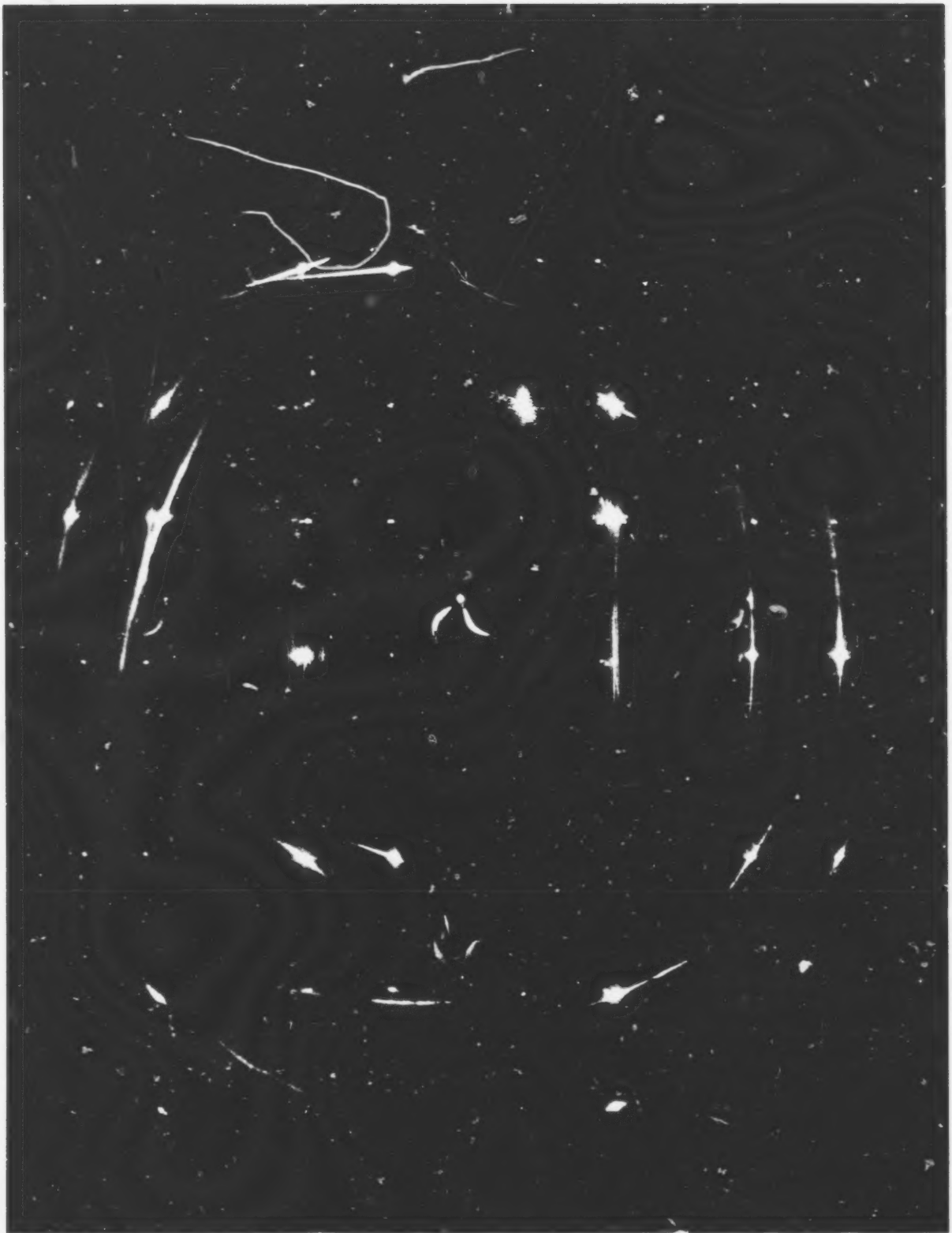
Aircraft thrust bearings

ORIGINAL PAGE
COLOR PHOTOGRAPH



Technician plasma spraying a high-temperature coating on a turbine blade

ORIGINAL PAGE
COLOR PHOTOGRAPH



Advanced turboprop model in the Lewis 8- by 6-Foot Supersonic Wind Tunnel

ORIGINAL PAGE
COLOR PHOTOGRAPH

Technology Utilization Services

We'd like you to think of NASA as a resource.

—Daniel G. Soltis

Every NASA field center has a Technology Utilization Office. Contacting any center will connect you to NASA's network of information and services. With a bit of imagination, you may be the next entrepreneur or company to introduce a new product to the American marketplace.

Technology Utilization Officers

Expert help in applying NASA's innovations to your needs

Technology Utilization officers will match your needs with the scientists and engineers who can assist you in solving your technical problems. The TU officer will also provide you with special publications detailing NASA's research.

Applications Teams

Problem-solving assistance to the private sector

Staffed by professionals, applications teams work to identify problems that might be solved by NASA technology. These teams have conducted projects in the areas of safety, health, transportation, and environmental protection.

COSMIC

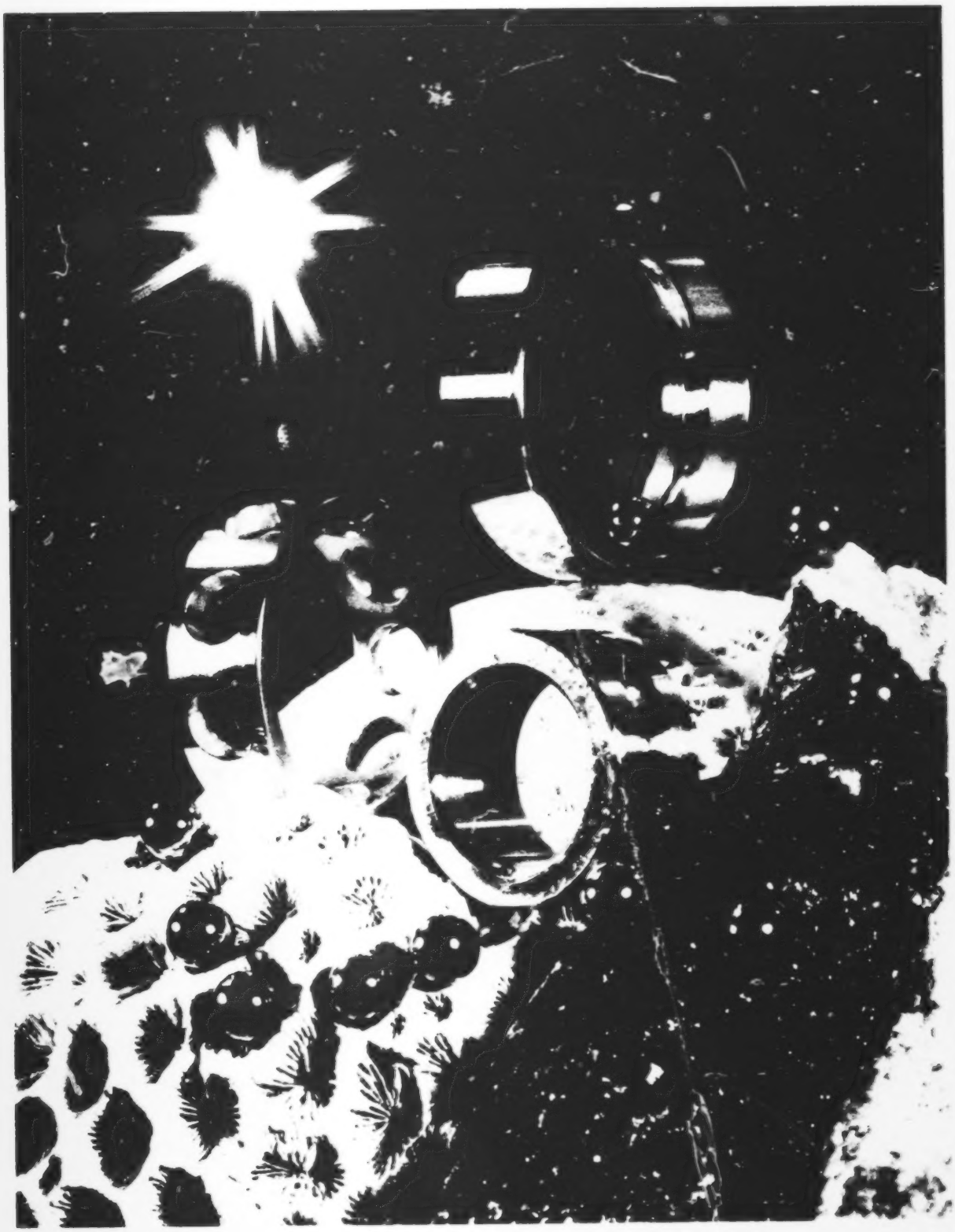
An affordable source of NASA's computer programs

The Computer Software Management and Information Center, COSMIC, is a library of thousands of computer programs and their documentation. For a nominal fee, you can access a variety of programs. General purpose programs include management and computer operations. Engineering programs perform tasks such as structural analysis, electronic circuit design, chemical analysis, and fluid systems design. Other programs determine building energy requirements and optimize mineral exploration.

Inventions for Licensing

Thousands of inventions available for licensing in the United States

To promote competition, NASA encourages nonexclusive licenses for commercial use of its inventions. If you invest your resources in the early commercial stages of an invention, an exclusive license may be granted. Generally, an exclusive license is issued for 5 to 10 years and requires royalties based on sales or use.



Bearings

ORIGINAL PAGE
COLOR PHOTOGRAPH

ORIGINAL PAGE
COLOR PHOTOGRAPH

Scientific and Technical Information Facility

A centralized office serving the professional community and the general public

The TI officers are here to help you. They have the right answer, the correct document, or the appropriate person in the NASA Technology Utilization Program. Just pick up the phone and give them a call.

State Technology Applications Centers

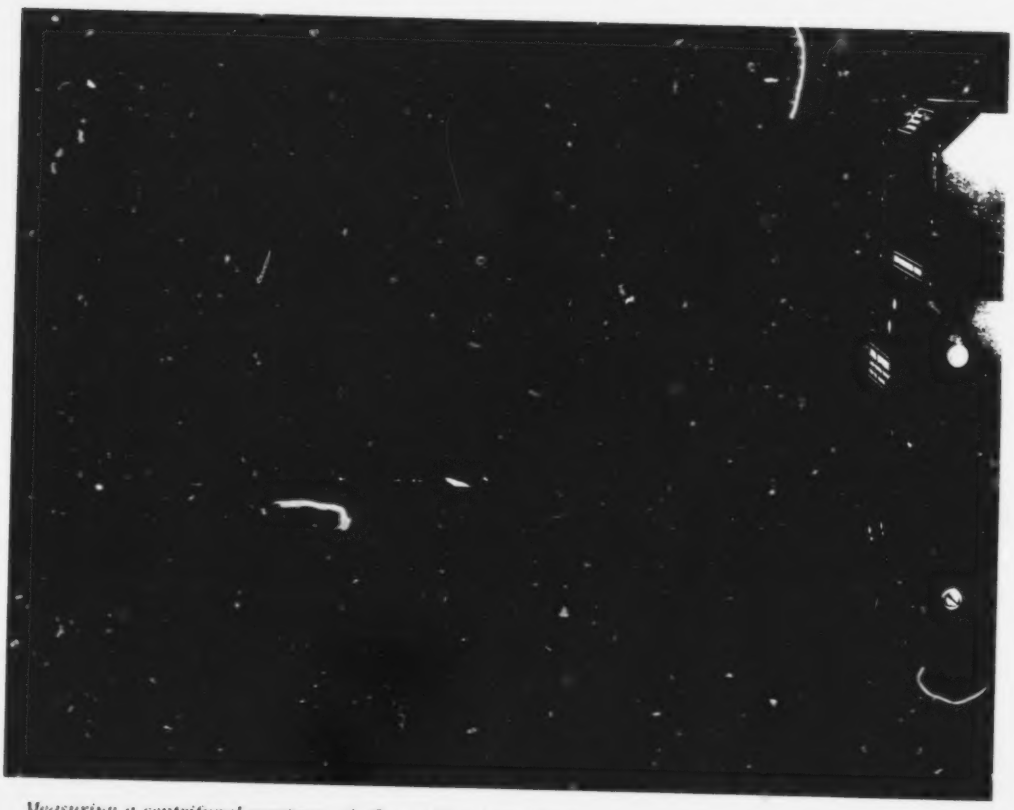
Technical information services for Florida and Kentucky

If you live in Florida or Kentucky, you can use the services of NASA's State Technology Applications Centers (STAC's). While the Industrial Applications Centers serve the states within their regions, the two State Technology Application Centers serve only their host states.

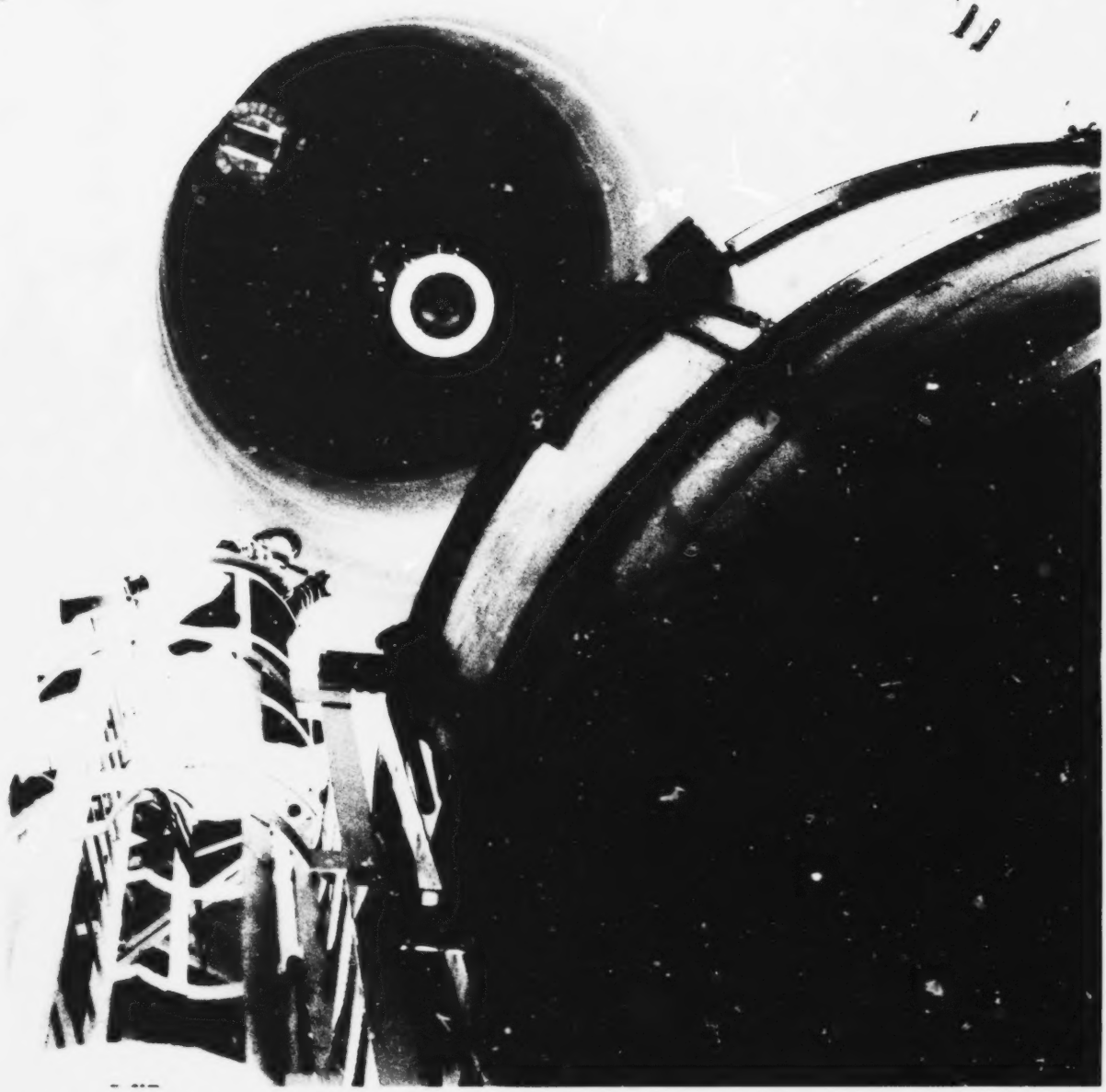
Industrial Applications Centers

Computerized access to 100 million documents

Computerized information retrieval from one of the world's largest data banks is available from NASA's network of Industrial Applications Centers (IAC's). The IAC's can help you access two million technical reports in the NASA data base, as well as reports and articles in 250 other data bases. Industrial Applications Centers also provide current literature about new developments in your area of interest.



Measuring a centrifugal compressor's flow with a laser beam



Lewis Zero-Gravity Research Facility

ORIGINAL PAGE
COLOR PHOTOGRAPH

ORIGINAL PAGE

From the Research Laboratory to the Marketplace

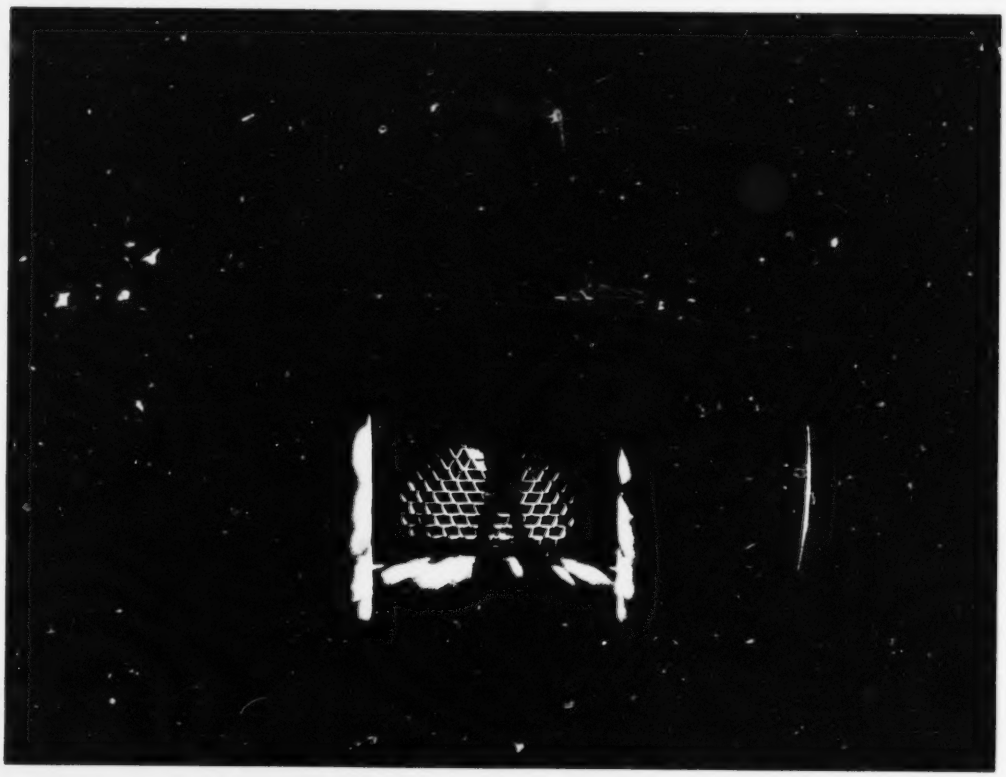
ORIGINAL PAGE
COLOR PHOTOGRAPH

Applications Projects

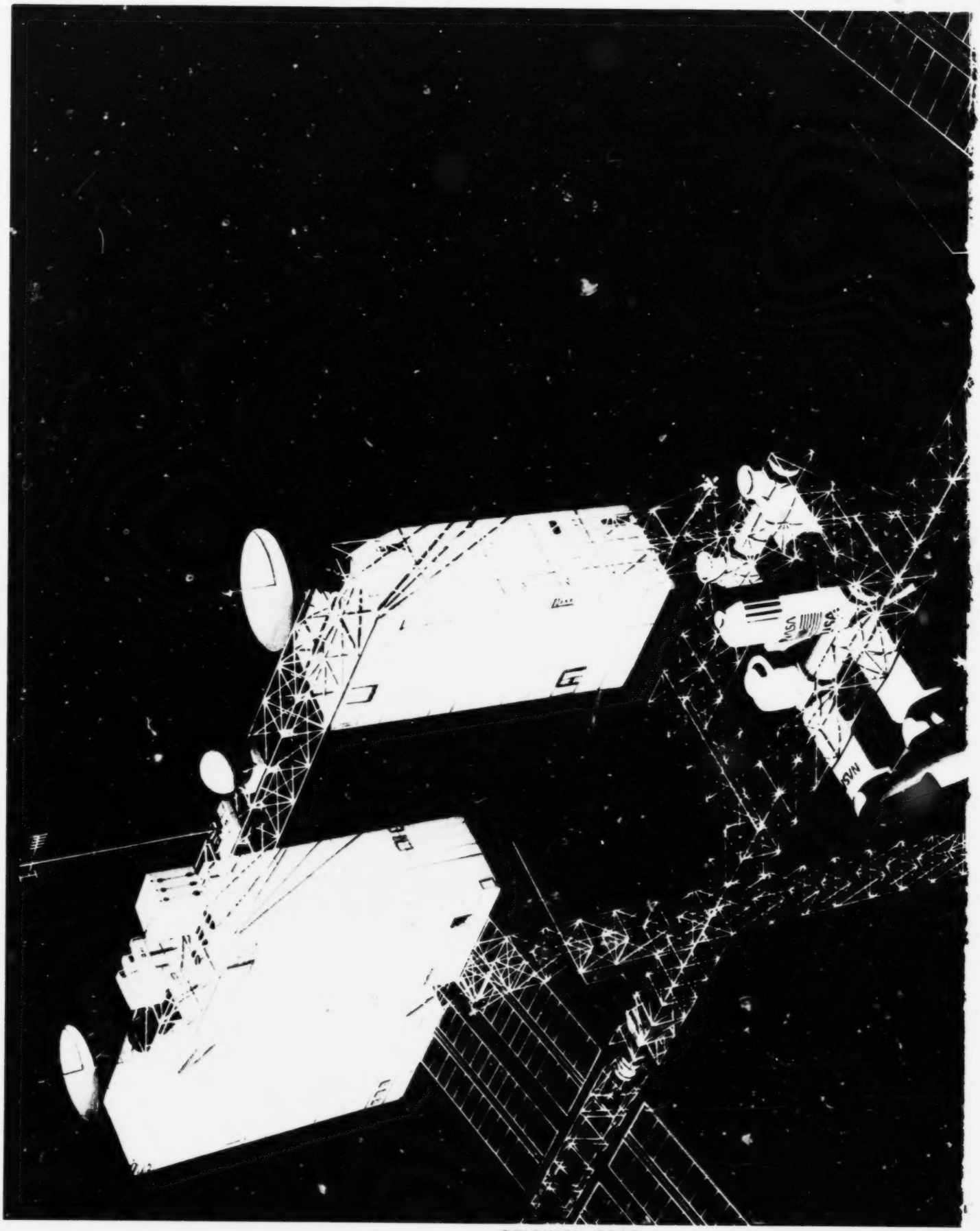
Transferring technology from the research laboratory to your local shopping center requires a carefully planned strategy. First, potential markets for the product are identified. After the product is designed, the production techniques are developed. Finally, the product is test marketed and advertised.

Most often, the market research and product development is performed by the entrepreneur. In this instance, NASA functions as an information resource. Occasionally, however, the private sector may not have the facilities necessary to adapt the aerospace technology. In this situation, the Technology Utilization Office may design an applications project in which NASA takes an active role in commercializing the technology.

Applications projects are tailored to the product and the company. The following spinoff stories illustrate the diversity and the stages of the technology utilization process. The Stirling engine project illustrates the experimental phase of the process. The klystron tube and riblet film projects present the final development and marketing stages. In the case of ferrofluids and PMR–15, the products have been on the market for years. Finally, IC 531 represents 20th century technology preserving 19th century craftsmanship.



Airflow straighteners in a NASA wind tunnel



ORIGINAL PAGE
COLOR PHOTOGRAPH

Dual-keel space station concept

ORIGINAL PAGE
COLOR PHOTOGRAPH

A New Engine for the Automotive Industry

The Stirling Engine

NASA has been the key to legitimizing the Stirling engine. NASA's impetus brought the Stirling technology from the Smithsonian to private industry.

—Greg Gutgsell, Stirling Engine Project Manager, Deere & Company

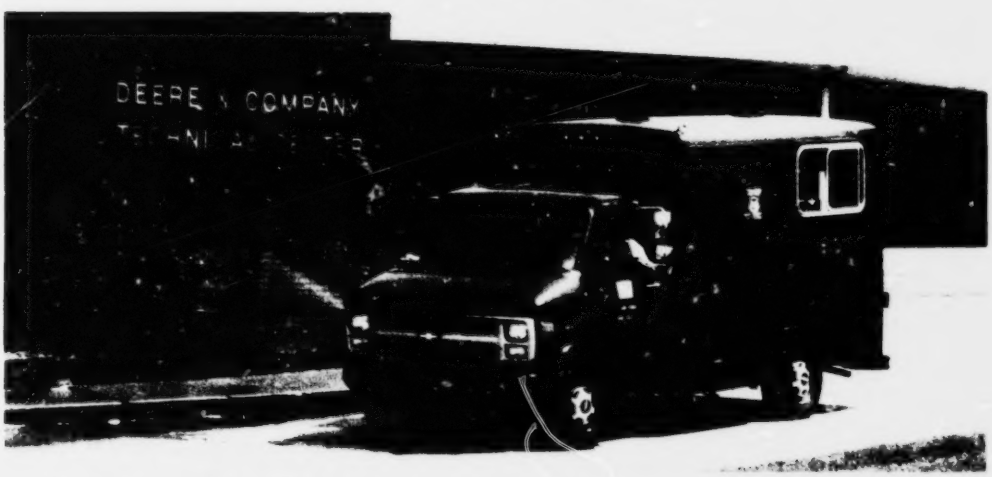
Technology utilization in progress

Imagine your automobile never needing an oil change, getting 41 mpg and accelerating from 0 to 60 mph in less than 13 seconds. Imagine your automobile without an exhaust system and with 50 percent fewer moving parts than a piston engine automobile. Such a machine would run cooler and would be easier to manufacture. Finally, since this engine would not be dependent on petroleum products, you could grow the fuel in your own backyard.

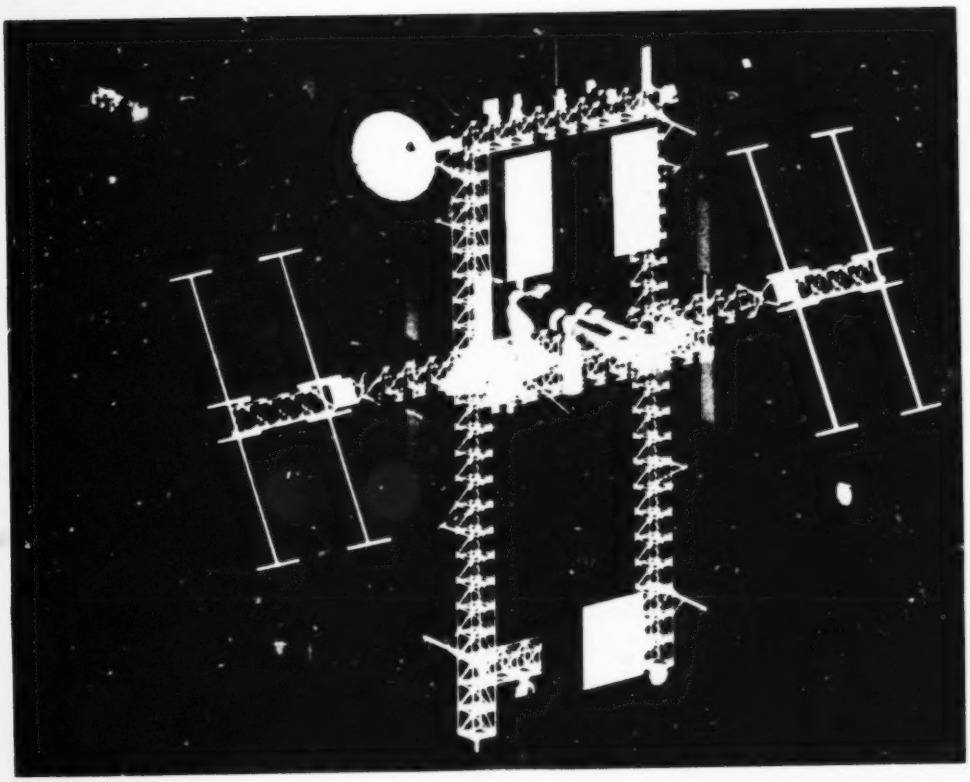
You might be surprised to discover that this "heat-cycle engine" is displayed at the Smithsonian National History Museum. Designed in the early 1800's, the Stirling engine was not considered for modern day use until the energy crisis of the 1970's. Since the Stirling can burn fuels ranging from natural gas to hardwood, NASA and the Department of Energy considered breathing new life into this antique technology. Before a commercial product could be brought to market, though, the energy crisis eased.

In the late 1970's the technical community sparked renewed interest in the Stirling. Deere & Company, the largest diesel manufacturer in the Western World, was tracking novel means of propulsion. Mechanical Technology, Inc., a prominent technological innovator, had created a modern version of the Stirling. And at NASA's Lewis Research Center in Cleveland, engineers were pursuing power sources for space applications. Through a series of conferences, NASA engineers drew MTI and Deere into the Stirling engine project as potential manufacturers. Since the Stirling equals

ORIGINAL PAGE
COLOR PHOTOGRAPH



Stirling-engine-powered delivery van



Stirling engines have the potential to generate electricity for space applications

or surpasses the most efficient diesel engine. Deere committed to evaluating and testing a Stirling engine mounted in a delivery van.

Test results from the prototype promise excitement for the automotive industry. In tests at Langley Air Force Base, the Stirling-powered van reached highway speeds and demonstrated surprising torque response. At present, Deere is in the process of converting a laboratory engine into a commercial product. If Deere can define the potential market and profitability of a Stirling engine delivery van, American consumers may be driving a Stirling-powered vehicle before the end of this century.

Few Americans are aware that NASA acts as a goodwill ambassador to American enterprise. In the case of the Stirling engine, a research group from NASA Lewis presented the merits of the Stirling to manufacturers and customers. As a result of their efforts, the U.S. Air Force, the Department of Energy, MTI, and Deere have partnered with NASA in the Automotive Stirling Engine Program. Potential customers include the Air Force, Purolator Courier, the American Trucking Association, and the U.S. Postal Service.

The Stirling engine, however, is just one of many products that NASA's Technology Utilization Program is transferring from the aerospace industry to the private sector.

ORIGINAL PAGE
COLOR PHOTOGRAPH

Multistage depressed-collector klystron tube

ORIGINAL PAGE
COLOR PHOTOGRAPH

Cutting Power Costs for UHF Television Stations

The Klystron Tube

Working with NASA has been a very positive experience.
--Earl McCune, Klystron Tube Project Manager, Varian Associates, Inc.

Technology utilization coming into the home stretch

Have you ever wondered why UHF television stations don't transmit the same picture quality as the major networks? One reason is that television transmitters are less efficient at UHF frequencies.

Because UHF stations broadcast at a higher frequency, a typical 2-million-watt UHF station spends about $150,000 a year for electricity—five times the amount a VHF station spends. To save money, UHF stations broadcast at reduced power. If you live within their broadcast range, you probably don't notice any difference in the quality of a UHF picture. But at greater distances, watching UHF stations can be more like listening to the radio.

Ironically, radio technology provided the basis for cutting UHF power consumption costs by 50 percent. In the early 1970's the NASA Lewis Research Center developed a radio wave amplifier that improved communications satellite transmissions. The Technology Utilization Office and the research engineers set the stage for relaying this satellite technology back to the Americans who had funded the project.

Since the early days of television, UHF stations have used klystron tubes to amplify their signals. Recognizing that this new radio wave amplifier technology would apply directly to the klystron tube, Lewis targeted its research for the UHF industry. With certain modifications, Lewis hoped to improve the energy-saving klystron tubes used by UHF stations.

Varian Associates, Inc., the largest manufacturer of klystron tubes in North America, recognized an opportunity to upgrade its product and joined the test project. Within 3 years, the venture cycled from computer simulations to a demonstration of the completed product—the multistage depressed-collector klystron.

Expected to be on the market by 1990, the enhanced klystron tube could save that 2-million-watt UHF station $75,000 per year. Nationwide, UHF stations could save an estimated $25 million a year.

How will this technology benefit Americans? UHF stations will broadcast a better-quality picture, and PBS patrons may notice a decrease in membership drives.

Jet Fuel Conservation Efforts Serving the World of Sports

Riblet Film

The riblet film provided a significant reduction in friction drag that translated into higher boat speed.
—John Marshall, coordinator of the Stars & Stripes *Design Team*

Classic technology utilization

On February 5, 1987, the racing yacht *Stars & Stripes* overwhelmed Australia's *Kookaburra III* with a 4-0 sweep and won the coveted sailing prize, the America's Cup. At the 1984 Los Angeles Olympics, the United States surprised the sports world by winning the silver medal in the four-oar-with-coxswain rowing event. In both cases an underwater advantage gave the Americans an edge over the foreign competition.

Applied to the hull of each vessel was a layer of riblet film. Tests by the *Stars and Stripes* design team showed that the film added an estimated ½ knot to the speed of the boat. At the Olympics, with the competition under way, engineers worked against the clock to apply the riblet film to the unseeded American's rowing shell. The results? Laurels for the United States teams.

The riblet technology resulted from NASA Langley Research Center's exploration of new ways to improve an airplane's fuel efficiency. Experiments showed that etching V-shaped grooves on an airplane's surface reduced wind friction drag.

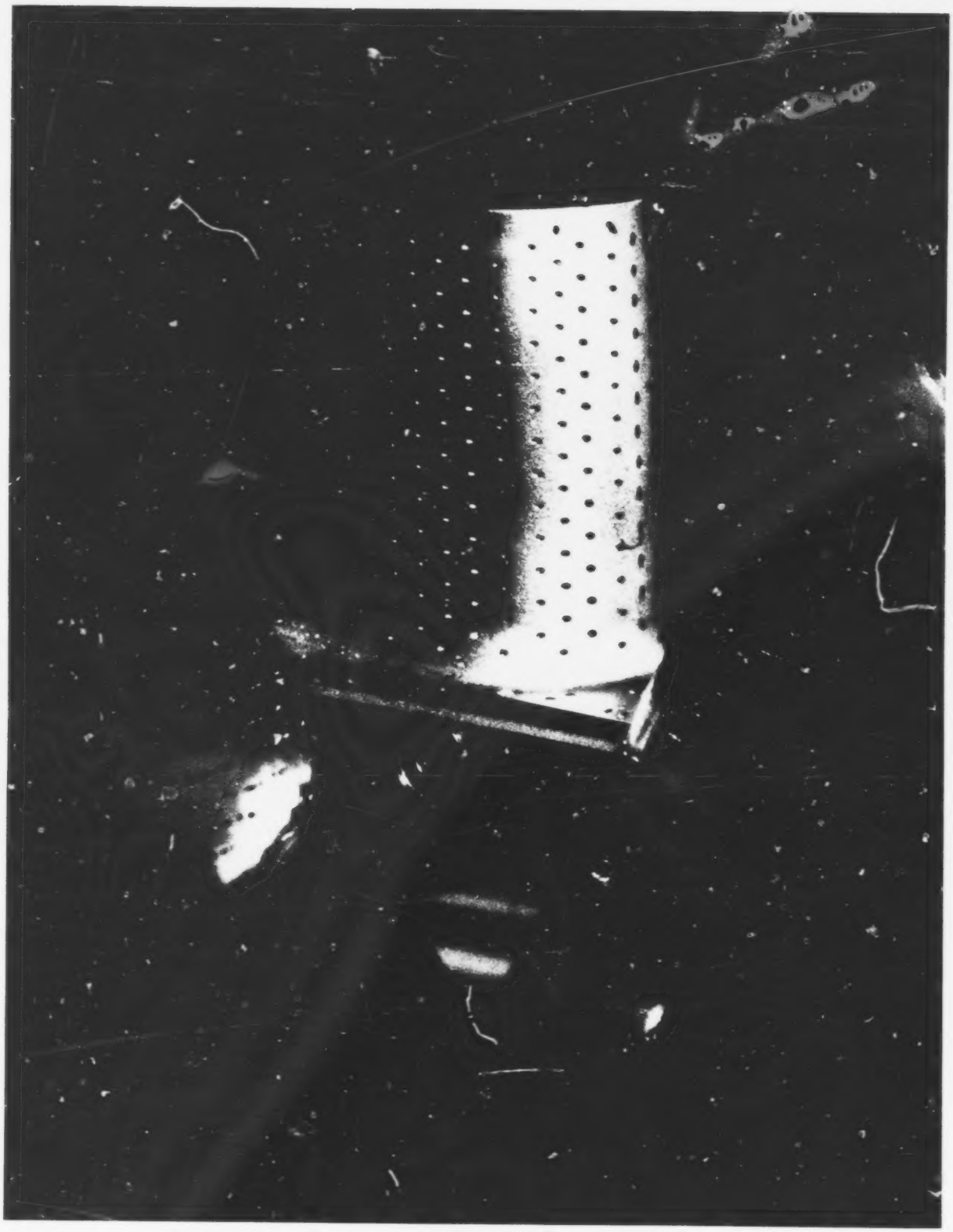
In 1980 a 3M Company engineer discovered an article about the riblet technology in the COSMIC publication *NASA Tech Briefs*. Originally, the riblets were machined on flat aluminum. The engineer suggested molding the grooves onto a lightweight plastic film, adding an adhesive backing, and pressing the sticky film onto the skin of an airplane, thereby providing an affordable modification. After talking with the Technology Utilization Office, 3M offered to design, produce, and test the riblets.

Encouraged by the results of wind tunnel tests, 3M reported its findings to the Boeing Company, the world's largest producer of commercial aircraft. At present, 3M and Boeing are working to bring the riblet technology to commercial aviation. If they are successful, riblet film could translate into a fuel saving of $200 million to $300 million per year.

Applying riblet film to a racing shell

PAGE
OGRAPH

GRAPH



High-temperature turbine blades for advanced gas-turbine engines

ORIGINAL PAGE
COLOR PHOTOGRAPH

COLOR ILLUSTRATION

Reinforced Plastic for High-Temperature Applications

PMR–15

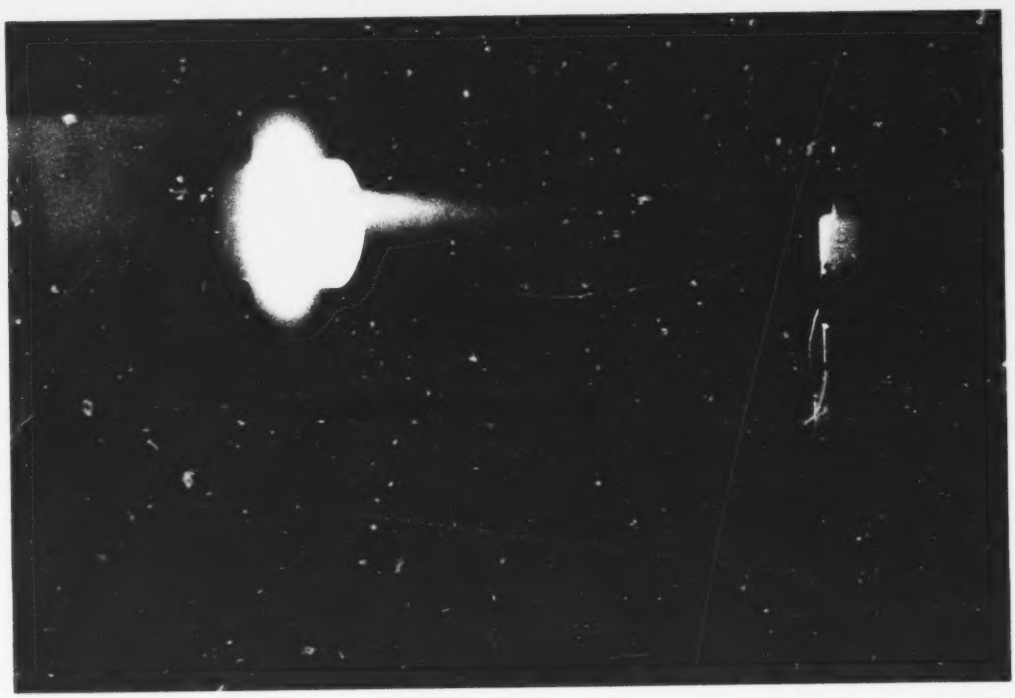
NASA responded to our customer's need for higher temperature resins in their jet engines.

—Walter Brueggemann, Materials Scientist, Ferro Corporation

Benefits for the aerospace industry

General Electric uses prepregs in jet engines. Hamilton Standard uses prepregs in jet engine nozzles. The supersonic wind tunnel at Arnold Engineering Development Center uses prepregs. In fact, the aerospace industry relies on prepregs, but what are they? Prepregs are materials that are impregnated with a resin.

With the significant cost of jet fuel, one of the goals of aerospace research is to decrease the weight of airplanes, thereby increasing fuel efficiency. In an effort to create lightweight, high-strength, and low-cost materials, Lewis Research Center developed an impregnating resin, PMR–15, that enhanced the temperature resistance of composites to a service temperature of 600 °F. Through the efforts of the Technology Utilization Office, Ferro Corporation, a leader in specialized composite materials, obtained the formula for PMR–15. After experimenting with the formula, Ferro developed a new material known as Ferropreg CPI 223™ R. With its resistance to high temperature, this composite material found acceptance in aircraft engines and structures.



Testing a high temperature composite material

ORIGINAL PAGE
COLOR PHOTOGRAPH

Giving New Life to Lady Liberty

IC 531

NASA's IC 531 formula is a permanent solution to steel corrosion. This technology will save millions of dollars in steel repair and replacement around the world.

—Parke Schaffer, Jr., President
Inorganic Coatings, Inc.

Technology utilization and industry—partners in restoration

When you think of the Statue of Liberty, you think of the symbols that represent the fabric of the United States—freedom, opportunity, independence. You probably do not think of the space shuttle. However, the launch gantries at the Kennedy Space Center provided the stimulus for Lady Liberty's corrosion-resistant coating.

In 1980 the National Park Service discovered corrosion and deterioration in the century-old Statue of Liberty. They set out on a 7-month search for a corrosion resistant coating that would protect the statue for the next 100 years. The search ended when Inorganic Coatings, Inc., introduced them to IC 531, a permanent coating developed by NASA.

Goddard Space Flight Center had developed a coating to protect launch gantries from the environment and the hot rocket exhaust of a space launch. Through a series of events, Inorganic Coatings, Inc., became the sole manufacturer and named the coating IC 531. Nontoxic and nonflammable, IC 531 creates a hard ceramic finish with excellent abrasion resistance—durable enough to preserve the 300-foot statue for centuries.

The statue's designer, Frederic Bertholdi, boasted that his creation would last as long as the pyramids of the Nile. However, he did not reckon with the environment and two million visitors a year. So while Lady Liberty represents the craftsmanship of 19th century engineers, the technology of 20th century engineers preserves that achievement.

From Fuel Pumps to Heart Pumps

Ferrofluids

NASA technology launched not just a single company but a new industry.

—Ronald Moskowitz, president of Ferrofluidics Corporation

A pay-off for risk-taking scientists

If you were a gambler, would you invest in a company that didn't have products or customers? Maybe, you say. What if that company's idea was to solve manufacturing problems with magnetized fluids? Well again, maybe not.

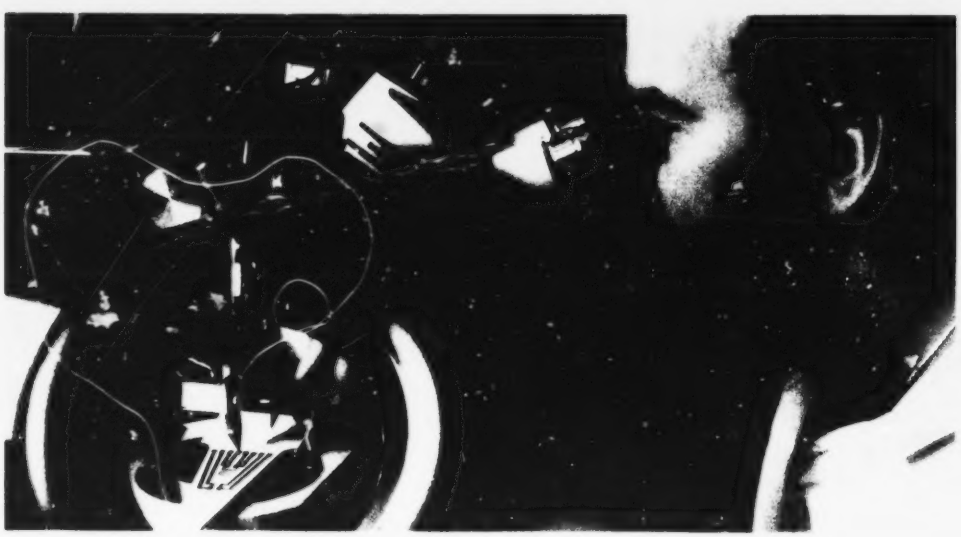
If you had invested in Ferrofluidics Corporation in 1969, you might have lost your shirt. Sales that year were $65,000. But if you had taken the risk, today you could retire on your dividends. The Ferrofluidics story is a striking example of the technology utilization process spinning off a new company and creating new jobs.

In the early days of the United States space program, a Lewis Research Center scientist discovered a solution to the problem of sending weightless fuel to the engine of an orbiting spacecraft. Magnetizing the fuel allowed it to be drawn into the engine by a magnet. These iron-enriched fluids were called ferrofluids.

In the mid-1960's Avco Space Systems Division faced a different problem. With one side of the spacecraft facing the sun and the other facing away from the sun, temperature control was crucial. Blending their expertise with NASA research, Avco developed a ferrofluid that cooled the hot side and warmed the cold side of an orbiting spacecraft.

Two enterprising Avco scientists realized that ferrofluids offered vast problem-solving potential in areas other than spaceflight. With a license from NASA for the technology, they left Avco in 1969 and formed Ferrofluidics Corporation. In their first year, they used ferrofluids to solve a manufacturing problem in the sealing of computer chips.

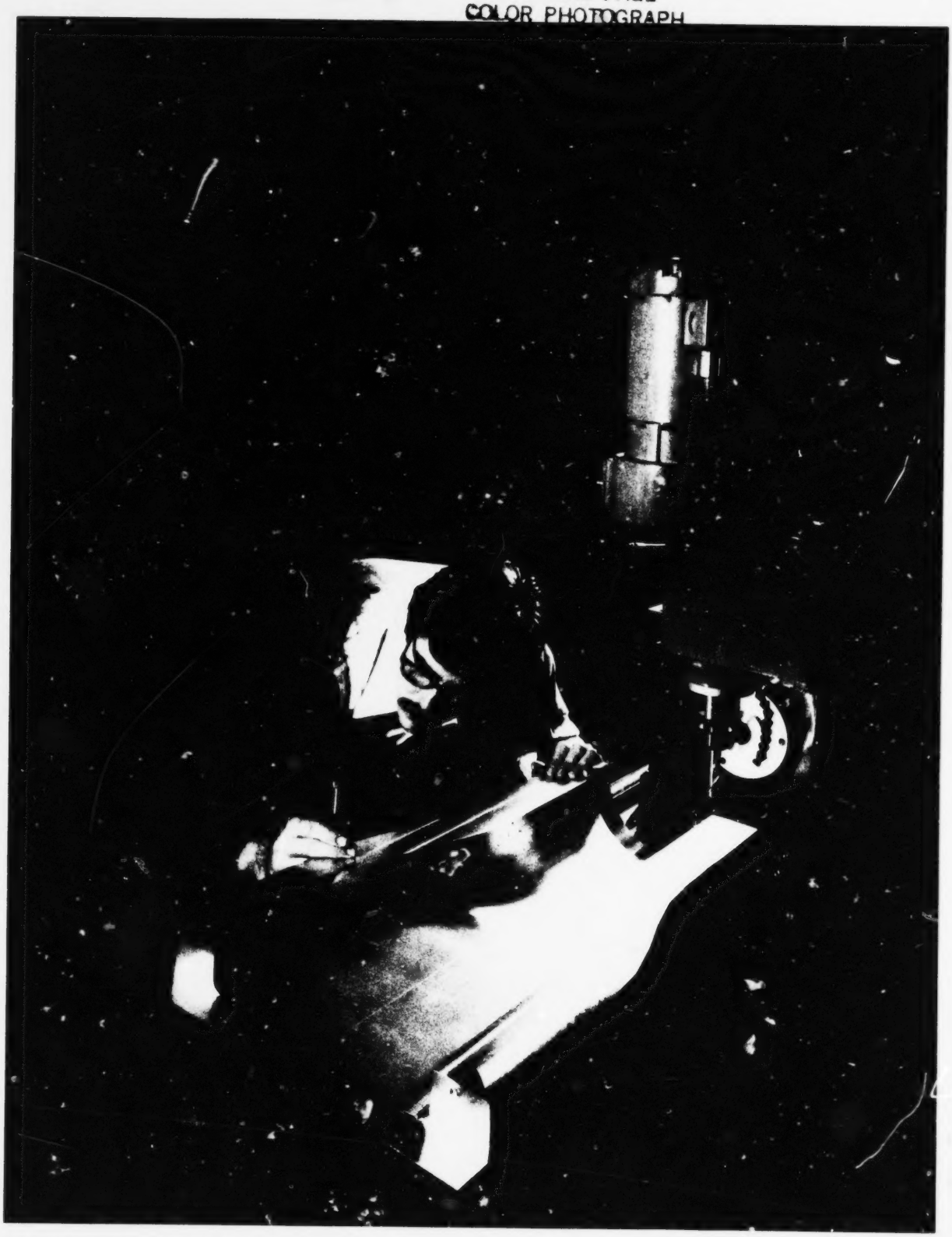
Since that time, ferrofluids have been used as cooling agents in stereo speakers and are finding growing acceptance in areas that range from artificial heart pumps to automated machine tools.



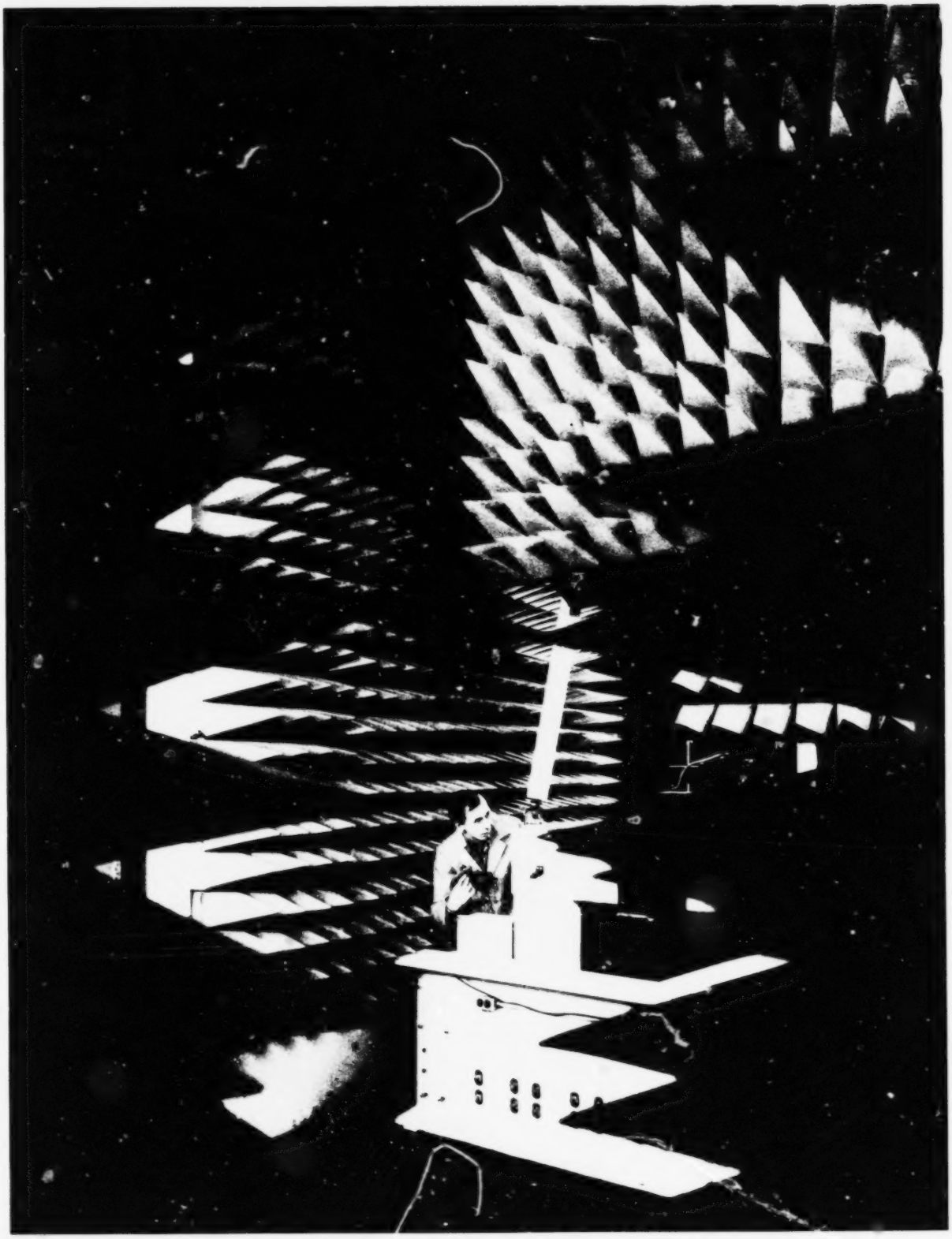
Technician examining a microcircuit

ORIGINAL PAGE
COLOR PHOTOGRAPH

ORIGINAL PAGE
COLOR PHOTOGRAPH



Computer-controlled machining of a transition duct



Near field antenna test facility

ORIGINAL PAGE
COLOR PHOTOGRAPH

Resources

Technology Utilization Officers

Leonard A. Ault
NASA Headquarters
Code IU
Washington, DC 20546
202/453-1920

Laurance A. Milov
NASA Ames Research Center
Mail Code 223-3
Moffett Field, CA 94035
415/694-5761

Donald S. Friedman
NASA Goddard Space Flight Center
Mail Code 702
Greenbelt, MD 20771
301/286-6242

Dean Glenn
NASA Lyndon B. Johnson Space Center
Mail Code EA1
Houston, TX 77058
713/483-3809

Thomas M. Hammond
NASA John F. Kennedy Space Center
Mail Stop PT-TPO-A
Kennedy Space Center, FL 32899
305/867-3017

John Samos
NASA Langley Research Center
Mail Stop 139A
Hampton, VA 23665
804/865-3281

Daniel G. Soltis
NASA Lewis Research Center
Mail Stop 7-3
21000 Brookpark Road
Cleveland, OH 44135
216/433-5568

Ismail Akbay
NASA George C. Marshall Space Flight Center
Code AT01
Marshall Space Flight Center, AL 35812
205/544-2223

Gordon S. Chapman
NAS Resident Office
Jet Propulsion Laboratory
Mail Stop 180-801
4800 Oak Grove Drive
Pasadena, CA 91109
818/354-8300

Robert M. Barlow
National Space Technology Laboratories
Code GA-00
NSTL Station, MS 39529
601/688-1929

Industrial Applications Centers

Aerospace Research Applications Center
611 N. Capital Avenue
Indianapolis, IN 46204
F. Timothy Janis, Director
317/262-5036

Central Industrial Applications Center
Southeastern Oklahoma State University
Station A, P.O. Box 2584
Durant, OK 74701
Dickie Deel, Acting Director
405/924-6822

NASA Industrial Applications Center
University of Pittsburgh
823 William Pitt Union
Pittsburgh, PA 15260
Paul A. McWilliams, Executive Director
412/648-7000

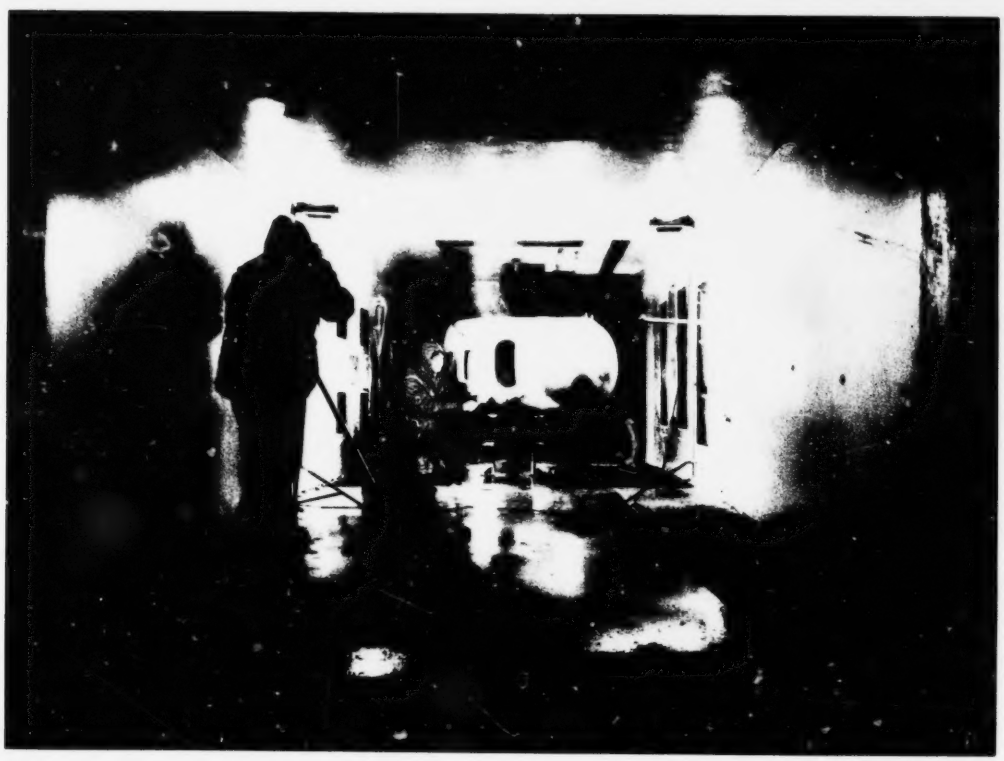
NASA Industrial Applications Center
University of Southern California
Research Annex, Room 200
3716 South Hope Street
Los Angeles, CA 90007
Radford G. King, Acting Director
213/743-8988
800/642-2872 (CA Only)

NASA/SU Industrial Applications Center
Southern University Department of
Computer Science
Baton Rouge, LA 70813
John Hubbell, Director
504/771-2060

NERAC, Inc.
One Technology Drive
Tolland, CT 06084
Daniel U. Wilde, President
203/872-6322

North Carolina Science and Technology
Research Center
P.O. Box 12235
Research Triangle Park, NC 27709
J. Graves Vann, Director
919/549-0671

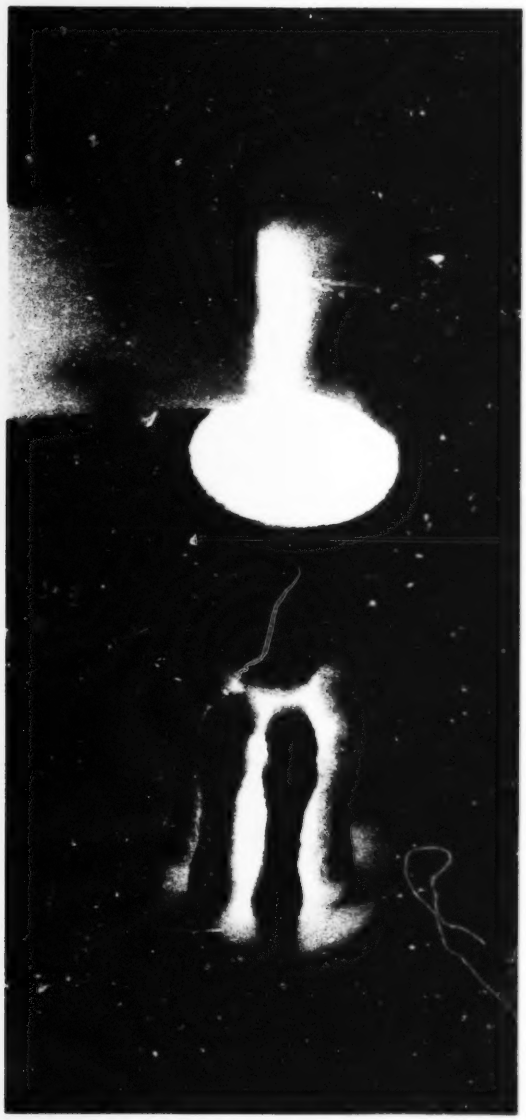
Technology Applications Center
University of New Mexico
Albuquerque, NM 87131
Stanley A. Morain, Director
505/277-3622



Preparing a test in the Lewis Icing Research Tunnel

ORIGINAL PAGE
COLOR PHOTOGRAPH

ORIGINAL PAGE
COLOR PHOTOGRAPH



Pouring tech. superalloy tensile test specimen

Application Teams

Technology Application Team
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709
Doris Rouse, Director
919/541-6980

COSMIC (Computer Software Management and Information Center)

COSMIC
University of Georgia
Computer Services Annex
382 East Broad Street
Athens, GA 30602
John A. Gibson, Director
404/542-3265

State Technology Applications Centers

NASA Southern Technology Applications Center
State University System of Florida
307 Weil Hall
Gainesville, FL 32611
J. Ronald Thorton, Director
904/392-6626

NASA UK Technology Applications Program
University of Kentucky
109 Kinkead Hall
Lexington, KY 40506
William R. Strong, Program Director
606/257-6322

Scientific and Technical Information Facility

NASA Scientific and Technical
Information Facility
Technology Utilization Office
Box 8757
BWI Airport, MD 21240
Walter M. Heiland, Manager
301/859-5300, Ext 241, 243

Patent Counsels

Robert F. Kempf, Assistant General
Counsel for Patent Matters
NASA Headquarters
Code GP
Washington, DC 20546
202/453-2424

Darrell G. Brekke
NASA Ames Research Center
Mail Code 200-11A
Moffett Field, CA 94035
415/694-5104

John O. Tresansky
NASA Goddard Space Flight Center
Mail Code 204
Greenbelt, MD 20771
301/286-7351

Edward K. Fein
NASA Lyndon B. Johnson Space Center
Mail Code AL3
Houston, TX 77058
713/483-4871

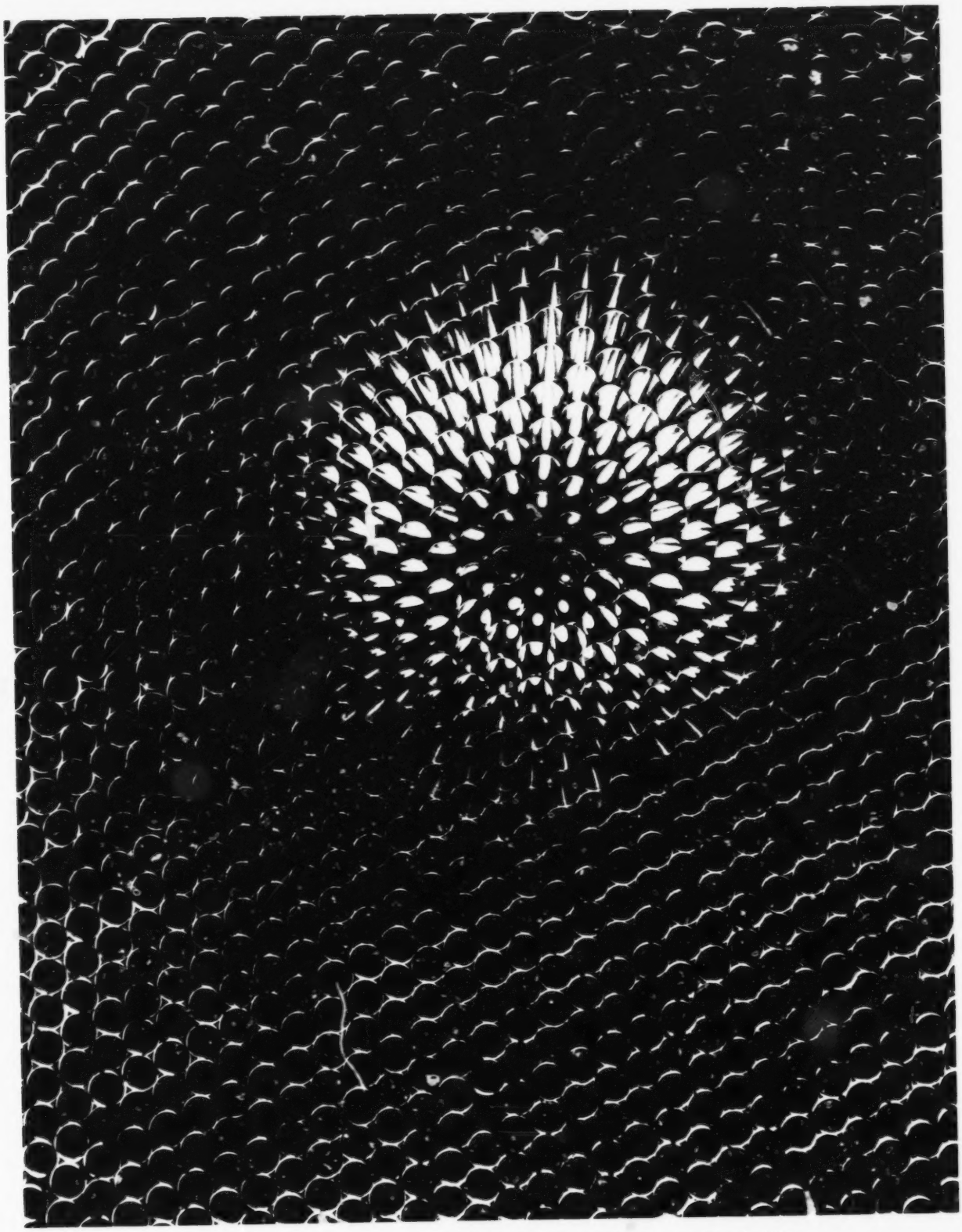
James O. Harrell
NASA John F. Kennedy Space Center
Mail Code PT-PAT
Kennedy Space Center, FL 32899
305/867-2544

George F. Helfrich
NASA Langley Research Center
Mail Stop 279
Hampton, VA 23665
804/865-3725

Gene E. Shook
NASA Lewis Research Center
Mail Stop 301-6
21000 Brookpark Road
Cleveland, OH 44135
216/433-5753

Leon D. Wofford, Jr.
NASA George C. Marshall Space
Flight Center
Mail Code CC01
Marshall Space Flight Center, AL 35812
205/453-0024

Paul F. McCaul
NASA Resident Office
Jet Propulsion Laboratory
Mail Code 180-801
4800 Oak Grove Drive
Pasadena, CA 91109
818/354-2734



106,000 soda straws provide uniform airflow for the inlet of the low-speed centrifugal compressor facility

ORIGINAL PAGE
COLOR PHOTOGRAPH

Acknowledgments

NASA and the Technology Utilization Office would like to thank the following companies for their contributions and assistance in bringing this publication to the marketplace.

Balloons to You
5335 Broadview Road
Parma, OH 44134
216/661-6100

The Boeing Company
Box 3707
Seattle, WA 98124
206/655-1131

Deere and Company
John Deere Road
Moline, IL 1265
309/752-8000

Eastman Kodak Company
343 State Street
Rochester NY 14450
716/724-4000

Ferro Corporation
1 Erieview Plaza
Cleveland, OH 44114
216/641-8580

Ferrofluidics Corporation
40 Simon Street
Nashua, NH 03061
603/883-9800

Inorganic Coatings, Inc.
1 Great Valley Parkway, Suite 8
Malvern, PA 19355
215/640-2880

Martin Mareitta
6801 Rockledge Drive
Bethesda, MD 20817
301/897-6000

Varian Associates, Inc.
611 Hansen Way
Box 10800
Palo Alto, CA 94303-0883
415/493-4000

3M Company
3M Center
St. Paul, MN 55144-1000
612/733-1110

ORIGINAL PAGE
COLOR PHOTOGRAPH